Kurram Tangi Dam Construction

Fisheries Management Plan

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Acronym	Term
EA	Environmental Assessments
FATA	Federally Administered Tribal Areas
IUCN	International Union for Conservation of Nature
KTMDP	Kurram Tangi Multipurpose Dam Project
KPK	Khyber Pakhtunkhwa
US	United States
WAPDA	Water and Power Development Authority

Fisheries Management Plan
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1 INTRODUCTION

The FATA Sustainable Development Plan 2006-2015 (Government of Pakistan 2006) includes the development of fisheries as one of the plans for the natural resource-based sector. Specifically, this Plan "aims to improve fisheries production to increase livelihood opportunities and diversify income, especially in the case of vulnerable groups and communities." The strategic measures identified to achieve this objective include the following:

- "Conserve natural fisheries resources, focusing on the most vulnerable stretches of rivers and streams. Increase the natural fish population in water bodies.
- Adopt measures to conserve aquatic biodiversity and improve ecosystem health.
- Facilitate the development of fisheries and fish-related industry."

The fisheries resource affected by the Kurram Tangi Multipurpose Dam Project (Project) consists of 64 species of fish (Table 7.1, Annexure I). The extent of the resource was determined from the literature, and by a limited fishery survey conducted in the Kurram and Kaitu Rivers in June and July 2013. The survey and its results are described in Annexure I. As determined in the survey, presently there is little fishing activity in the Kurram or Kaitu rivers and no commercial fishery exists. Fishing activity by local fishermen is for their own consumption. Therefore, in accordance with the FATA Sustainable Development Plan 2006-2015, the objectives of the Fisheries Management Plan are to sustain the existing indigenous fisheries resource and to develop a new potentially commercial fishery in the Project reservoirs.

The Fisheries Management Plan for the Project will consist of implementing the mitigation actions recommended for Aquatic Resources in Sections 5.2, 5.3 and 5.4 of the EA. During construction of the Kaitu Weir (Component I), and Kurram Tangi Dam and Weirs II and III (Component II), mitigation actions focus on minimizing adverse impacts on the aquatic habitat. This will be accomplished by containment/treatment of water contaminated by petroleum products, hazardous materials or human wastes, and by avoiding or minimizing the use of in-river gravels, especially in riffle areas, as borrow materials. Gravel deposits along the river bank will be used in preference to in-river deposits. If the use of in-river deposits cannot be avoided, preference will be given to use deposits that will be inundated by the impoundments. If the use of downstream deposits cannot be avoided, then the use of gravels from riffle areas will be minimized.

During Project operation, mitigation focuses on maintaining the exisiting fishery communities in the Kaitu and Kurram rivers, as well as developing reservoir fisheries. This will be done by: 1)minimizing fish entrainment into hydropower facilities; 2)providing an Ecological Flow downstream of the Kaitu Weir, Kurram Tangi Dam, Weirs II and III, and the Kurram Garhi Headworks; 3) providing a fishway at the Kaitu Weir, if one is found to be warranted; and 4) stocking the Kurram Tangi Reservoir and Weir III reservoir. The existing baseline information on the Kurram and Kaitu Rivers is insufficient to determine the details needed for the effective design of these Project operation mitigation actions. Therefore, prior to implementing any of these mitigation programs, an intensive and comprehensive fish and water quality survey of these rivers will be completed.

2 FISH AND WATER QUALITY SURVEY

The design of the fish and water quality survey begins by establishing sampling sites, sampling methods and sampling frequency. The survey needs to be of sufficient duration to establish seasonal changes in water quality characteristics and movements of species, and, thus, will be conducted over the whole calendar year. Ideally, the survey would be conducted for at least two years prior to any construction activity of the Project. However, because of security concerns, it is assumed that the survey would begin during the construction of Component I. To determine the impacts of the KTMDP, the survey needs to continue as a monitoring program for a period of five years following the start-up of each Project component.

Sampling Sites. Sampling sites will be located in the reach of the Kurram River extending from the Kurram Garhi Headworks to the Pakistani border with Afghanistan; those in the Kaitu River from the Pakistani border with Afghanistan to the confluence of the Kaitu with the Kurram. The sites in the Kurram River will be located upstream and downstream of the Kurram Tangi Dam, Weirs II and III and the Kurram Garhi Headworks, and within the portions of the river to be impounded (or now impounded in the case of the Headworks) by these structures. Similarly, the sites in the Kaitu will be located upstream and downstream of the Kaitu Weir, as well as in the portion of that river to be impounded. To the extent possible, the sites will be outside the influence of construction areas.

It is assumed that the sites sampled during the June and July 2013 fish survey (Annexure I) will be included in the comprehensive fish and water quality survey. A reconnaissance survey of the Kaitu and Kurram Rivers will be conducted prior to the year-long study to determine the location of additional sampling sites. The selection of sites will include the major types of riverine habitat (viz, riffles, runs, glides and pools). The exact location of the sites will depend on access and security concerns.

Sampling Methods. The focus of the fish survey will be on the Species of Concern (species listed by IUCN as Endangered; http://www.iucnredlist.org) and Representative Important Species described, with the rationale for their selection, in Section 4.7.3 of the EA. These species are listed in **Error! eference source not found.** below.

Table 2-1: Fish Species of Concern and Representative Important Species in the Kaitu and Kurram Rivers by Project Component

Species	Component I	Component II	Component III
Salmophasia punjabensis		x	x
Barilius pakistanicus		x	
Cirrhinus mrigala			x
Labeo dyocheilus	x		
Puntius punjabensis			x
*Tor putitora**			
Garra gotyla	x	x	
Racoma labiata		x	
Schizothorax plagiastomus		x	
Schistura curtistigma		x	
Sperata seenghala			x
*Glyptothorax kashmirensis**			
Glyptothorax naziri		x	
Ompok bimaculatus			x
Wallago attu			x
Mastacembelus armatus		x	x

* = Species of Concern

Additionally, because the benthic macroinvertebrate community and its density in these rivers is presently unknown, this community will be included in the sampling program. The sampling methods to be used at a site will depend on the habitat being sampled. Because no single type of sampling gear will capture all the species that are present at a site, multiple gear types will be used, when appropriate. It is assumed that electrofishing and net sampling (by cast net and or seine) would be the principal methods used in the fish survey. The appropriate sampling methods at a site will be determined in the reconnaissance survey. Sampling for benthic macroinvertebrates will be done using a D-net or a Surber Sampler.

Water quality parameters measured during the sampling effort at a site will include water temperature, level of dissolved oxygen, pH and turbidity. With the exception of turbidity, the other parameters will be measured *in situ* using appropriate field meters. (It is assumed that such instrumentation will be permitted during the Project construction period. If not, water temperature will be taken using a hand-held thermometer and the other parameters will be analyzed in the laboratory.)

A description of the physical habitat at a site will be recorded based on visual observation. The river width, channel type (braided, meander, straight), type of habitat (riffle, run, glide or pool), water depth, type of substrate and water velocity (fast moderate or slow) will be recorded. In conjunction with the Ecological Flow studies (described below), quantitative measurements of water depth and velocity will be made along transects at some sites during the spawning and maintenance seasons of the Species of Concern and Representative Important Species (Table 2-1).

Sampling Frequency. The sampling efforts need to be sufficiently frequent to determine the timing of seasonal fish movements. Because fish move in response to changes in water temperature and river flows, and move within the water column during warmer water temperatures, the sampling frequency will be adjusted accordingly. Thus, sampling would be once per month during the warmer months (April - September), and then three times during the colder months (October - March), as conditions permit. During the winter, some sites in the upper reaches of these rivers may not be sampled if they are ice covered.

Sample Handling and Data Analysis. Fish collected in the survey will be identified to species; benthic macroinverterbrates will be identified to lowest practical taxon. Fish will be identified, counted and measured (total length) in the field, and released at the site of capture. Exceptions will be those specimens that cannot be identified in the field, and "voucher" specimens [(1)]. These, and all benthic macroinvertebrates, collected at a site will be preserved and identified in the laboratory.

Additionally, all adult specimens of the Golden Mahseer (*Tor putitora*) and *Glyptothorax kashmirensis* will be marked with a color and numerically-coded external tag and released at the site of capture to determine their migratory habits and distances moved during the survey. The location and date of fish so marked will be recorded according to species. Subsequent recaptures will be noted in the field sheets and tabulated in survey reports.

Water quality results and habitat information will be reported with the fish and macroinvertebrate data on a monthly basis. The data will be used in conjunction with the Ecological Flow studies and reservoir stocking plans. The need for a fishway at the Kaitu Weir will also be determined on the basis of results of fish movements determined during the survey.

(1) Voucher specimens confirm the presence and identity of a species at a site. These specimens are initially stored at the facility of the investigator or developer, then usually donated to a university museum.

3 FISH ENTRAINMENT MITIGATION

Fish entrained into the intake of the KTMDP powerhouses will be subject to turbine-induced mortality. Most (over 90 percent) of the fish entrained will be small (less than 4 inches in length), and can be expected to experience 5 percent to 6 percent mortality, while larger fish (8 inches or longer) passing the turbines can be expected to experience 10 percent to 30 percent mortality (Section 5.2.4.6 of the EA). This impact will be of minor significance for most species in the Kaitu River, but can be of moderate significance to significant for one of the Species of Concern, Golden Mahseer (*Tor putitora*) because of its migratory habits.

The loss of fish as a result of turbine-induced mortality can be mitigated by maintaining a low approach velocity to the hydropower intakes. The trashrack clear spacing should be designed to allow only small fish to pass through. Based on extensive studies of fish entrainment at hydropower projects in the US, an approach velocity to the trashrack of 0.5 fps, and a trashrack clear spacing of 2 inches is recommended as mitigation.

4 ECOLOGICAL FLOWS

Initial estimates of the Ecological Flows to be released by the Kaitu Weir, Kurram Tangi Dam, Weirs II and III, and the Kurram Garhi Headworks were determined using the Tennant Method (Tennant 1976) and reported in Sections 5.2.4.6, 5.3.3.6 and 5.4.3.6, respectively, of the EA. These flows, provided below in Table 4-1, need to be validated and adjusted, as needed. The Tennant Method does not address biological parameters, and may not be sufficient to sustain the fish populations in affected downstream reaches of river. When natural river flows fall below the Ecological Flow, the minimum release flow will be the Environmental Flows (the flows required for downstream human consumption and waste assimilation) described in Sections 5.2.3.6, 5.3.3.6 and 5.4.3.6 of the EA, plus flows required to meet downstream irrigation needs.

Table 4-1: Ecological Flows Determined Using the Tennant Method (Tennant 1976) by Site and Seasonal Flow Period

Site	Ecological Flow (cfs) Low Flow Months (September to June, on average)	Ecological Flow (cfs) High Flow Months (July and August, on average)
Kaitu Weir	144	215
Kurram Tangi Dam	176	263
Weir II	212	318
Weir III	266	400
Kurram Garhi Headworks	269	403

Ecological Flow studies will be conducted in the affected reaches of river downstream of the Kaitu Weir, Kurram Tangi Dam, Weirs II and III, and the Kurram Garhi Headworks using a habitat modeling method, such as the Physical Habitat Simulation (PHABSIM) system developed by the US Fish and Wildlife Service (Bovee, 1982). The method proposed for use in this Fisheries Management Plan is the hydraulic simulation model, Riverine Habitat Simulation (RHABSIM 3.0), an extensive conversion of PHABSIM (Thomas R. Payne and Associates Software, http://trpafishbiologists.com). This software is now in the public domain and available (free) on the Internet.

The data required for RHABSIM analysis include water depth and velocity, and type of substrate measured at intervals along several transects perpendicular to shore at a site. Study sites will be selected based on the Fish and Water Quality Survey described above. The required transect measurements of water depth, velocity and substrate type will be made in conjunction with the Fish and Water Quality Survey.

Additionally, "target species" need to be selected to determine the Ecological Flow for the affected reach of river. These species will also be selected based on the Fish and Water Quality Survey. It is assumed that the Species of Concern, the Golden Mahseer (*Tor putitora*) and *Glyptothorax kashmirensis*, will be target species. Other target species will be selected based on the Representative Important Species collected in the affected reach during the Fish and Water Quality Survey. Habitat Suitability Indices will then be determined for the target species, again relying on the data obtained during the Fish and Water Quality Survey. Habitat Suitability Indices will be determined for spawning habitat and for habitats used for rearing and maintenance (feeding and growth).

The optimum flows for the target species during their spawning seasons and the rest of the year will then be determined based on the Habitat Suitability Indices and RHABSIM model simulations. The Ecological Flows will be determined based on the habitat use in an affected reach by the target species, selecting the flow that corresponds to the maximum amount of habitat available for spawning and maintenance for most of the target species. The Ecological Flow can be expected to vary seasonally in accordance with habitat use for spawning or maintenance.

5 KAITU WEIR FISHWAY

The Golden Mahseer was found in the Kaitu River at Spinwam during the 2013 fish survey (Annexure I). This species may spawn up to three times per year from April to November, with primary spawning in March and April (Gurung et al., 2002), and will migrate many miles upstream to spawn in the headwaters of large rivers. The species requires cold, free-flowing turbulent water, and areas having large pools and rapids, sand bars and gravel for spawning (Shrestha, 2002). According to Shrestha, adults of this species return to spawn in the area of a river in which they emerged from the spawning bed. Thus, adult Golden Mahseer in the lower Kaitu River that began life upstream of the weir can be expected to migrate (perhaps a considerable distance) upstream of the weir to spawn. The Kaitu Weir will block this spawning migration to the upper Kaitu River, denying access to over 70 miles of river above the weir that is potentially valuable spawning and rearing habitat.

Golden Mahseer were also collected in the Kurram River at Manduri, Shiwa Bridge and Fida Alam (all above the Kurram Tangi Dam site) during the 2013 fish survey (Annexure I) and were found at Bannu (Mirza et al 2008). The species can, thus, be expected to be found in the Kurram River between Bannu and the Kurram Tangi Dam site. It is very likely that Golden Mahseer downstream of the Kurram Tangi Dam site migrate into the upper Kurram River to spawn (although this remains to be determined by the Fish and Water Quality Survey). When constructed, the Dam and Weirs II and III will block these spawning migrations. Weir III and the Dam are too high for a conventional fish ladder, and a fish lift or lock is not economically justified. Assuming that the Kurram River population of Golden Mahseer will "stray" for spawning, alternative spawning sites for this population need to be accessible in the Kaitu River. These migrations may also be blocked by the Kaitu Weir.

If Golden Mahseer populations in the Kaitu River below the Weir and Kurram River are found to migrate into the reach of the Kaitu River above the Weir during the Fish and Water Quality Survey, this will necessitate a fishway (or other technical solution) at the Kaitu Weir. This will especially be the case if Golden Mahseer are stocked in the Weir III reservoir (see Reservoir Fisheries below). In addition to Golden Mahseer, other species can be expected to pass upstream of the Kaitu Weir via a fishway. Kullander et al (1999) opined that *Glyptothorax kashmirensis* would utilize a fish ladder.

Wickstrom (1999) studied the use of two fishways (a Denil, and a "pool type with orifices and notched overflow" design) on the Jhelum River by species that also occur in the Kurram River. Of the species in common, *Schizothorax plagiostomus*, a Representative Important Species in the Kurram River, and two species of *Glyptothorax* were found using the fishways. Wickstrom concluded, however, that a vertical slot fishway would be better than either type of fishway studied because of the fluctuations in Jhelum River flows. (Information on the design and operation of Denil, "pool type with orifices and notched overflow," and vertical slot fishways is provided in Katapodis, 1992; and Lay, 2009. Internet web sites for these sources are provided in the reference section.)

Schwalme et al (1985) found that a vertical slot design effectively passed a wide variety of north-temperate, non-salmonid species in North America, passing thousands of cyprinids (*Notropis hudsonius*) during May and June of 1984. Similarly, Travade et al (1998) found that the vertical slot design passed a wide variety of fish species, including many cyprinids (the dominant family of fishes in the Kurram and Kaitu rivers) at two dams in France. Given the fluctuations in flows in the Kaitu River, and the likelihood of success of passage by Golden Mahseer and *Glyptothorax kashmirensis*, a vertical slot design is recommended for the Kaitu Weir.

Clay (1995) provides the details of the design of a vertical slot fishway. These fishways are usually built on a 1V:10H slope (Katopodis, 1992). The Kaitu Weir is 18 feet high. Assuming the invert of the fishway at its upstream exit is three feet below the weir crest (to allow operation of the fishway when the impoundment is not at full pool), this would result in a fishway 150 feet long, based on a drop of 1 foot between pools. However, Clay (1995) recommends a drop of 0.75 feet between pools, to allow weak swimming species to ascend the fishway. Doing so will extend the fishway length to 200 feet. As is the case with any fishway, the location of the entrance is critical to its success in passing fish upstream. Usually, the entrance is placed at the base of the barrier. Therefore, the entrance of the fishway would be at the base of the Kaitu Weir, and the fishway would double back on itself in a "zig-zag" fashion, which is typical of most installations of fishways.

It needs to be emphasized, however, that recommending the construction of this (or any) fishway at the Kaitu Weir will be predicated on the clear need to do so based on the results of the Fish and Water Quality Survey, and follow-up monitoring surveys (see below). If these surveys show that migratory species, such as Golden Mahseer, below Spinwam do not now ascend the river above the weir site, if suitable spawning habitat does not exist upstream of the Weir site, or if an alternative technology (such as constructing spawning channels downstream of the weir) is more appropriate than a fishway based on topography, then no fishway will be needed. What is recommended in this Fishery Management Plan is the preparation of a conceptual design of a vertical slot fishway in conjunction with the final design of the Kaitu Weir. If shown to be needed, it can then be easily retrofitted at the weir.

6 RESERVOIR FISHERIES

One of the priorities for fisheries in the FATA Sustainable Development Plan 2006-2015 is to "develop dam fisheries and pond/reservoir fisheries." The impoundments formed by the Kaitu Weir and Weir II will be too small to support a commercial fishery. However, these impoundments can be expected to result in population increases of indigenous species now present in the Kaitu and Kurram rivers that can adapt to the impoundments. Although small, these water bodies will serve as a refuge to the local fish fauna during periods of low flow in the Kaitu and Kurram rivers and their tributaries, especially during winter when water temperatures are low. As such, these impoundments will provide an improved source of recruitment to sustain the riverine populations of the species that adapt, as well as be a resource for subsistence fisheries by local fishermen.

The Kurram Tangi Reservoir and Weir III Reservoir will be suitable for the development of commercial fisheries. Potential species for stocking in these reservoirs include Thaila (*Catla catla*), Mrigal (*Cirrhinus mrigala*), Rohu (*Labeo rohita*), Golden Mahseer (*Tor putitora*), Silver Carp (*Hypophthalmichthys molitrix*) and Grass Carp (*Ctenopharyngodon idella*). All these species are considered "Species of Special Importance in Pakistan" and all have a "very high" commercial value (Rafique and Khan 2012). These species are presently bred artificially and raised in hatcheries in Pakistan. Fingerlings of these species for stocking are readily available at these hatcheries and have been stocked in the Baran Reservoir (see Table 7.1, Annexure I) and other WAPDA reservoirs (Mirza, et al. 2012).

The geographic distribution status of these species in Pakistan (Rafique and Khan 2012), estimated average weight gain following one year after stocking as fingerlings, and their respective commercial values in terms of current market price (PKR per kg) on the basis of size of fish in a year are provided in Table 6-1. Based on this information, the species recommended for stocking in the Kurram Tangi Reservoir and Weir III Reservoir in this Fisheries Management Plan are also provided in Table 6-1.

Table 6-1: Potential Fish Species for Stocking in the Kurram Tangi Reservoir and Weir III Reservoir, with Distribution Status in Pakistan, Estimated Average Weight Gain One Year After Stocking, Current Market Price and Recommendation for Stocking in the Project Reservoirs.

Species	Geographic Distribution Status in Pakistan	Estimated Average weight gain (kg) one year after stocking	Current Market Price (PKR per kg)	Recommended for Stocking
Thaila	Indigenous	1.5	200	Yes
Mrigal	Indigenous	1	150	Yes
Rohu	Indigenous	1	200	Yes
Golden Mahseer	Indigenous	1	200	Yes
Silver Carp	Exotic	1.5	110	No
Grass Carp	Exotic	1.5	150	No

As shown in Table 6-1, Silver Carp and Grass Carp are not recommended for stocking in the Kurram Tangi Reservoir or the Weir III Reservoir. These species are exotic in Pakistan and can cause adverse impacts on the local populations of native fish species in the Kurram and Kaitu rivers. In other parts of the world (India, the Middle East, China, Poland and the United States) where these exotic species have been introduced, their introduction (usually accidental) has resulted in the reduction in populations of the native fish fauna (Kolar, et al. 2007). Following the accidental introduction of Silver Carp in the Gobind Sagar Reservoir in India, the populations of Thaila, Rohu and Golden Mahseer declined (Ibid). Further, these exotic species comprised only about 5 percent of the fishery production in the Mangla Reservoir on the Indus River (Mirza, et al 2012). Based on the potential problems associated with stocking Silver Carp and Grass Carp (especially the likely adverse impact on endemic and indigenous fish populations in the Kurram and Kaitu rivers), and their comparative commercial values in relation to the other candidate species, these exotic species should not be introduced into the Kurram River above the Kurram Ghari Headworks; and, therefore, should not be stocked in either the Kurram Tangi Reservoir or the Weir III Reservoir.

In contrast, stocking indigenous species that have an equal or greater economic value to Silver Carp and Grass Carp would produce multiple benefits. As described in Section 5.3.3.6 of the EA, a reservoir stocking program for the Golden Mahseer was recommended as mitigation for blocking the present spawning migrations of this species by the Kurram Tangi Dam, and Weirs II and III. This species is successfully reared in hatcheries in Nepal and farmed in rivers there (Gurung et al 2002, Joshi et al 2002 and Shrestha 2002). It is, therefore, feasible to rear and farm Golden Mahseer in the Kurram and Kaitu rivers in addition to developing a commercial fishery for this species in the Kurram Tangi Dam and Weir III reservoirs.

Golden Mahseer not only has a "very high" commercial value, both as a food fish and a game species, it is also listed as Endangered by the IUCN (http://www.iucnredlist.org/details/166645/0). Thus, in addition to its commercial value, stocking this species would increase its population in Pakistan. (Stocking to restore threatened and endangered fish species has been found to be a fruitful practice in many instances as a conservation measure.) Further, in interviews with local fishermen on the Kurram River, this species was identified as being the most sought after (Annexure I).

The final selection of fish species to be stocked is the responsibility of the reservoir fisheries manager. However, for the purposes of this Fisheries Management Plan, it is assumed that Thaila (*Catla catla*), Mrigal (*Cirrhinus mrigala*), Rohu (*Labeo rohita*) and Golden Mahseer (*Tor putitora*) will be stocked annually. These species are indigenous to the Indus River drainage and can be expected to be syntopic with the Kurram River fish species in the Project area (see the Fish Distribution Maps, Section 7.5, Annexure I). All the species recommended for stocking are present in the Baran Reservoir, just downstream of the Kurram Garhi Headworks (see Table 7.1, Annexure I). Golden Mahseer and Mrigal were also collected in the riverine portions of the Project area. (As seen in Table 7.1, Annexure I, Golden Mahseer was collected at Bannu and just upstream of the Kurran Tangi Dam site in the Kurram River, and at Spinwam in the Kaitu River. Mrigal was collected in the Kurram at Bannu.) Based on their wide distribution in the Indus River drainage, Thaila and Rohu are also likely present in the reach of the Kurram upstream of the Kurram Garhi Headworks. (This will be confirmed during the Fish and Water Quality Survey.) As such, no adverse impacts are anticipated as a result of stocking these species in the Project reservoirs.

Fingerlings of these species can easily be obtained from hatcheries in KPK and Punjab provinces. The fish seed of Rohu, Mrigal and Thaila is readily available at the Carp Hatcheries of the Department of Fisheries, KPK in the Bannu District. Golden Mahseer is artificially bred, raised to fingerling size, and is readily available at the Mahseer Fish Seed Hatchery (Gariala) and Mahseer Nursery Unit, (Hatian) in the Attock District of Punjab Province (adjacent to KPK province). Because the Golden Mahseer is a Species of Concern in the Kurram and Kaitu rivers, it will be given priority as a species for stocking in the Project reservoirs. Developing a fishery for this species will also be a priority.

Fish seed stocking rates in reservoirs cannot be prescribed as a general formula, as is done for ponds. The stocking rate in reservoirs depends on the size of the reservoir, its biota, the species to be stocked and their availability, the presence of predators, the productivity and carrying capacity of the reservoir and, most importantly, the breeding success or annual recruitment of indigenous and transplanted species. In the initial years of stocking, however, 250–500 fingerlings/ha/year may be stocked (Sreenivasan, 1984).

Although a fingerling size of 12.5 cm is recommended for stocking in reservoirs, usually fish of this size are not available in large numbers at the fish seed hatcheries. Moreover, the transportation of large sized fingerlings is difficult and expensive. Thus, fingerlings 6-10 cm in length will be stocked. The stocking rate of fingerlings in the Kurram Tangi Reservoir and Weir III will depend upon the carrying capacity of the respective reservoirs. The estimation of the carrying capacity of these reservoirs is only possible after they are filled and will depend upon the fertility (nutrient level) of the water. A low nutrient level in the water will lead to poor production of natural food and ultimately will result in poor fish growth and survival. Stocking fingerling numbers beyond the reservoir's carrying capacity will also have a negative impact on the growth and survival of the stocked fish. It is important to note that 30 percent (perhaps even more) of the total fingerlings stocked in the reservoirs can be expected to be lost. This high mortality is usually due to predation, starvation and non-adaptation to the new aquatic environment. However, keeping in mind all these factors, it is estimated that the stocking rate of these reservoirs will be about 500 fingerlings/ha during the initial stocking, and then in the following years, the rate will be reduced by 50 percent to 250 fingerlings/ha. The anticipated stocking ratio among the fingerlings of these five fish species is provided in Table 6-2.

Table 6-2: Proportional Fingerling Stocking Ratio, Estimated Average Weight Gain per Year and Contribution to the Yield of Fish Species to be Stocked in the Kurram Tangi Reservoir and Weir III Reservoir.

Species	Proportional Stocking Ratio (Percent)	Estimated Average Weight Gain per Year (kg)	Contribution to Yield on the Basis of Growth Rate (Percent)
Thaila	30	1.5	40
Mrigal	15	1	15
Rohu	40	1	30
Golden Mahseer	15	1	15

However, a period of several years will be required following reservoir formation before fish stocking should begin and a harvest of the stocked fish can follow. Following the filling of the Kurram Tangi and Weir III reservoirs, mercury in the inundated soils will be released into the water column. Although the levels of mercury in the soils in the Project Area are unknown, a representative mercury level for sandstones, limestones and shales (the surface and near-surface rocks in the Kohat Plateau, on the western limb of the Bannu Basin in which the Project is located; see Section 4.2.2.1 of the EA) is reported as 0.01 *ug*/g to 0.3 *ug*/g (Bringmark 1997). This inorganic mercury will become bio-available (due to methylation) and will be bioaccumulated in fish. Time is needed for a reduction in the methyl-mercury concentrations to reduce the risk of mercury contamination in fish. In some reservoirs, the time for mercury concentrations to return to pre-impoundment levels is more than 10 years (Bodaly et al 1997), and even longer in reservoirs with wetlands.

The period needed to reduce the risk of harvesting mercury contaminated fish in the Kurram Tangi and Weir III reservoirs will likely be much less than 10 years (perhaps, only two or three years). There are no wetlands in these reservoirs and little emergent vegetation will be submerged by reservoir filling (major factors in the formation of methylated mercury in the aquatic ecosystem). Further, the maximum methyl-mercury concentrations in fish are anticipated to be low because the water is slightly alkaline. Concentrations of methyl-mercury are lowest in deep, eutrophic lakes with long hydraulic residence times and highest in acidic, humic waters (Meili 1997). Finally, the level of methy-mercury in the aquatic biota depends on the methylation-demethylation balance in the aquatic ecosystem and the trophic level of the organisms.

Levels of mercury are lowest in algae and plankton, and highest in piscivorous fish. Meili (1997) reported that mercury concentrations in the muscle tissue of large piscivorous fish reached 4 mg/kg in acidic lakes and rivers, but was only 0.1 mg/kg in very large, deep lakes; whereas the corresponding levels in large herbiviorous fish were only 10 percent of those levels (0.4 mg/kg in acidic waters and 0.01 mg/kg in large, deep lakes). Mercury levels in Mrigal in Tarbela Reservoir averaged 0.250 *ug*/g, 0.319 *ug*/g in Chashma Reservoir and 0.580 *ug*/g in Llyod Reservoir (Ashraf et al. 1991). The World Health Organization criterion for the limit of mercury in fish is 0.5 *ug*/g (Agorku et al. 2009). However, these reservoirs on the Indus River receive industrial and municipal discharges that contain mercury. Because the Kurram Tangi and Weir III reservoirs do not receive such discharges, mercury levels in the fish fauna in these reservoirs will be substantially lower. Nonetheless, the fish fauna will require monitoring for mercury before stocking should begin.

A period of time will also be required for fingerling-sized stocked fish to reach harvestable size. The growth rate of fish in these reservoirs depends upon water quality (especially temperature) and the availability of natural food. Among the proposed four fish species, Thaila has the best growth rate (subject to availability of abundant food). Golden Mahseer will have the lowest growth rate among these species (based on reports of its growth potential). Nonetheless, it is expected that Thaila, Rohu and Mrigal will attain harvestable size after one year of stocking as fingerlings. However, Golden Mahseer usually takes more time than the other species to reach its harvestable size, but can also attain a weight of one kg in a year following stocking of fingerlings in the wild if food is abundant and water temperature is warm. Shrestha (1997) reported that Mahseer grows better in wild than in captivity.

7 MONITORING ACTIVITIES DURING PROJECT OPERATION

7.1 Fish and Water Quality Survey

The Fish and Water Quality Survey efforts conducted prior to (or during) Project construction will continue for five years following the start of Project operation to determine the impacts of the Project (including fish entrainment) on the fish communities of the Kurram and Kaitu Rivers. The sampling sites, methods and procedures established in the initial surveys will be employed in this phase of monitoring. However, the frequency of monitoring may be reduced sequentially over the years, depending on results.

7.2 Ecological Flows

The Fish and Water Quality Survey efforts conducted prior to (or during) Project construction will continue during Project operation to monitor the effectiveness of the Ecological Flow established first by the Tennant Method (Tennant 1976), then adjusted using the habitat model RHABSIM. Sampling methods, procedures and frequencies will be those employed in the Fish and Water Quality Survey. However, the sampling sites will be primarily those in the Fish and Water Quality Survey located within the river reach under the influence of the Ecological Flow, plus a control site located upstream of the flow release site. The control site will also be one previously studied in the Fish and Water Quality Survey.

Flows will be measured at the site of release and established sampling sites. To facilitate these measurements, staff gages need to be established with rating curves near these sites. The flows at these sites will be checked with flow meters at regular intervals for purposes of quality assurance, and discrepancies resolved by an experienced hydrologist.

Monitoring will continue for a period of five years to evaluate the changes in water quality and resulting changes in the fish and benthic macroinvertebrate fauna. Water quality changes will be evaluated based on water quality criteria to sustain aquatic life. Because Pakistan has no such criteria, the International Water Quality Guidelines for Aquatic Ecosystems (Global Water System Project, http://www.gwsp.org/current-activities/water-quality-guidelines.html) currently under development and scheduled for completion in 2014 are proposed for use in the Kurram and Kaitu rivers. The changes in fauna will be evaluated based on the baseline Fish and Water Quality results. If needed, the Ecological Flows will be adjusted based on the monitoring.

7.3 Kaitu Weir Fishway

The Fish and Water Quality Survey efforts conducted prior to (or during) Project construction will continue during Project operation to determine the need for a fishway at the Kaitu Weir. Sampling methods, procedures and frequencies will be those employed in the Fish and Water Quality Survey. If no fishway exists at the Kaitu Weir, the sampling sites will be those employed in that survey that are located downstream of the Weir to determine changes in relative abundance in the fish fauna as compared with the baseline conditions established in the pre-operational period. Sampling will continue over a period of five years following the start of operation of Component I.

If a fishway is constructed at the Kaitu Weir, monitoring will consist of determining the effectiveness of passage by the fishway. This will entail monitoring the fish using the fishway by collecting fish within, and at the upper end and entrance of the fishway. If Golden Mahseer are found to congregate at the fishway entrance, a fish mark-and-recapture study (or, ideally, a radio-telemetery study) may be conducted to evaluate different flow regimens in the fishway so as to optimize upstream passage.

7.4 Reservoir Fisheries

Frequent monitoring is required to determine the changes in the fish assemblages in the reservoirs. In addition to biological sampling, water quality parameters (dissolved oxygen, pH, temperature and turbidity) need to be monitored because of their significant impact on success of fish reproduction and rearing. Additionally, Golden Mahseer cannot reproduce within the reservoir environment. The species can be maintained in reservoirs exclusively by stocking. However, this is expensive and not necessarily desirable from the perspective of population genetics (especially when attempting to restore a river's population). If Golden Mahseer cannot find suitable spawning habitats upstream of the Weir III Reservoir, the fishery for this species in that reservoir may require annual stocking. This can only be determined based on a well-designed monitoring program.

WAPDA, with the help of FATA Fisheries Department or Research Groups, can monitor the fish biodiversity in the reservoirs in conjunction with the operational phase of the Fish and Water Quality Survey to observe the distribution of indigenous fish species in the reservoirs and to determine the stocking schedule for selected species. Prior to stocking, the fish collected from these reservoirs will be monitored annually for mercury concentrations. When these concentrations have reached a safe level for human consumption of fish (to be determined in consultation with health professionals), stocking can be initiated. Monitoring then will continue for a period of five years after the initial stocking of fingerlings to develop conservation strategies for managing the reservoir fisheries. The monitoring program will include the following steps:

- Fish sampling sites/stations will be determined during a reconnaissance survey within both reservoirs.
- Fish sampling will be carried out nine times a year.
- Fish sampling will be carried out using cast nets, gill nets and boat electrofishing gear.
- Weight-length relationships will be developed from the fish collected from different locations to determine the growth performance of fish stock.
- Water quality parameters especially dissolved oxygen, pH, temperature and turbidity will be done using digital meters at each event of fish collection.
- Fish specimens to be monitored for mercury concentration will be prepared following standardized procedures (such as those utilized by the Utah Division of Water Quality 2011) and sent to the laboratory for analysis.
- The data will be compared with the baseline fish stocking data to monitor the reservoir health.
- Fish growth rates, species composition, relative abundance and condition factors (K) for the selected fish species will also be determined.

8 COST ESTIMATES

It is assumed that, initially, the WAPDA Fisheries Department will carry out the Fisheries Management Plan and monitoring activities, and that the FATA Department of Fisheries will assume various tasks after a period of time to be determined by those agencies. Although these agencies presently conduct similar activities at other locations, it is likely that additional personnel and equipment will be needed to carry out this Fisheries Management Plan. The extent of additional resources required is unknown. Therefore, the estimates presented below are the total costs for each of the respective parts of the Plan.

8.1 Fish and Water Quality Survey

Prior to conducting the Fish and Water Quality Survey, a reconnaissance survey will be conducted to establish sampling sites. It is estimated that a crew of two men can do this reconnaissance in five days (including travel). Thus, 10 man-days will be required for the reconnaissance.

A field crew of three men (minimum) will be required to conduct the Fish and Water Quality Survey. Sampling will be done nine times per year. Assuming each sampling event will require 10 days (five days on the Kaitu and five days on the Kurram; including travel times), a total of 270 man-days per year will be needed for the field portion of the survey. An additional 30 man-days per year is estimated to be needed for data analysis and report preparation, resulting in 300 man-days per year for the survey. This level of effort may be reduced during the five-year period following the start-up of a Project Component.

Equipment required for the survey will include collecting gear (a backpack electrofishing unit, cast net, seine), tagging equipment and miscellaneous gear (waders, buckets, measuring board, bottles, formalin, field books, etc.). Water quality sampling equipment will include a dissolved oxygen meter (which also measures temperature), pH meter and sample bottles. A flow meter and transect measuring equipment will be required to determine flows. If the equipment must be purchased, approximately $15,000 US is estimated as the cost.

For the purposes of this cost estimate, it is assumed that water quality measurements for water temperature, dissolved oxygen and pH will be made *in situ* and only turbidity will be determined in the laboratory. Assuming water samples will be taken at 20 sites during the survey, sampling nine times per year, 180 water samples per year are to be analyzed for turbidity.

8.2 Ecological Flow Studies and Monitoring

Data for the Ecological Flow modeling effort will be obtained as part of the Fish and Water Quality Survey. An estimated 45 man-days will be needed to conduct the RHABSIM model runs and determine the Ecological Flows at all the sites (Kurram Tangi Dam, Kaitu Weir, Weirs II and III, and Kurram Garhi Headworks).

The monitoring effort for the Ecological Flows will be a continuation of the Fish and Water Quality Survey. Sampling methods and frequencies (nine times per year) will be those employed in that survey. However, because the number of sampling sites will be reduced to three (or less) per barrier, it is assumed each sampling event will require five days for both rivers. Therefore, 45 man-days per year will be needed for the field portion of the monitoring. An additional 15 man-days per year is estimated for data analysis and report preparation. The monitoring will thus require 60 man-days per year. In the first year, a total of 105 man-days will be needed to include the modeling effort. Over the five-year study period, a total of 345 man-days will be needed for the program.

It is assumed the equipment obtained for the Fish and Water Quality Survey will be used for the Ecological Flow monitoring effort. Thus, the only additional cost would be for renewable supplies and laboratory analysis of water samples for turbidity. The RHABSIM software is free.

8.3 Kaitu Weir Fishway Design and Monitoring

Preparing a conceptual design of a vertical slot fishway for the Kaitu Weir will require the services of an experienced fisheries engineer. Because such designs are well established and the hydraulic characteristics of this type of fishway are already known, it is assumed that the design effort can be completed in 10 man-days.

During the period no fishway is present at the Kaitu Weir, the monitoring effort to determine the need of a fishway will be a continuation of the Fish and Water Quality Survey. Sampling methods and frequencies (9 times per year) will be those employed in that survey. It is assumed that the monitoring efforts evaluating the Ecological Flow at the Kaitu Weir will also serve to monitor the need for a fishway. Therefore, there is no additional cost for this portion of the monitoring.

If a fishway is installed at the Kaitu Weir, monitoring the fishway will require sampling, and mark-recapture studies during the period of the year it is in operation. It is assumed that the fishway will only be in operation during the period of upstream migration of the target species. For the purposes of this cost estimate, it is assumed that the target species upstream migration occurs in March and April. Assuming a crew of three men, monitoring the upstream migration five days per week, every other week over a two-month period (five weeks total), a total of 75 man-days will be needed for the field portion of the monitoring effort. Assuming an additional 15 days is needed for data analysis and report preparation, a total of 90 man-days will be needed for the monitoring effort.

If the sampling and tagging equipment used in the Fish and Water Quality Survey is used to monitor the fishway, no additional equipment costs will be incurred for this monitoring.

8.4 Reservoir Fisheries

Cost of Fish Stocking

Kurram Tangi Reservoir: The estimated water surface area of KTMD is 10939 acres (4427 ha) and average depth of 116 ft. Initially, fingerlings will be stocked at the rate of 500/ha. The estimated cost of 1,000 fish fingerlings (including transportation charges) is $100 US. A total 2,213,500 fingerlings (500/ha) will be stocked during the first year of filling of the reservoir. The estimated expenditure on initial fish stocking during first year will be $221,350 US. In following years, the stocking rate will be 250 fingerlings/ha/year. Thus, during the second year, a total 1,106,750 fingerlings will be stocked, which will result in an expenditure of $110,675 US. The total expenditure of five years for fish stocking Kurram Tangi reservoir will be $664,050 US.

Weir III Reservoir: The water surface area of Weir III reservoir has been estimated as 730 acres (295ha) with an average depth of 57 ft. Thus, a total 147,500 fingerlings (500/ha) will be required for initial stocking during the first year in this reservoir, and its cost (along with transportation charges etc.) will be $14,750 US. In the following four years, a total 295,000 fingerlings (73,750 per year @ 250/ha/yr) will be required, resulting in an expenditure of $29,500 US. The total estimated cost of fingerling stocking in the Weir III reservoir for five years is $44,250 US.

Fish Yield: Sugunan (1995) reported that supplemental stocking of small impoundments in India can yield on average 146 kg/ha/year. Thus, the fish yields of the Kurram Tangi Reservoir and the Weir III Reservoir are estimated (approximately) as 646,342 and 43,070 kg/yr (146 kg/ha/year), respectively.

Cost of Reservoir Monitoring:

A reconnaissance survey of the reservoirs will be conducted to identify sampling sites. It is estimated that two men can do this reconnaissance in 8 days (including travel). Thus, 16 man-days will be required for the reconnaissance.

A field crew of four men will be required for fish sampling and observations of water quality parameters. This field study will be done 9 times per year. Each survey/study will require 11 days (8 days on the KurramTangi Reservoir and 3 days on the Weir III Reservoir; including travel times), resulting in a total of 396 man-days per year needed for the field study/survey of both the reservoirs. Additionally, approximately 40 man-days per year will be required for data analysis and report preparation. Thus, a total 436 man-days per year will be required for collection of field data and report development.

The materials/equipment required for this survey/study will include a 4x4 vehicle, dissolved oxygen meter, pH meter, turbidity meter, fish gill nets, cast nets, boat electrofisher and a number of miscellaneous field accessories (i.e. digital weighing balance, measuring board, buckets, bottles and preserving chemicals). Approximately $40,000 US will be required if these all items are to be purchased for this effort.

The cost of mercury analysis in fish tissues requires specialized equipment and analytical capabilities that are presently available in Pakistan. However, the cost/sample for the analysis is unknown. The total cost will depend on the number of species monitored. This has yet to be determined. However, the analysis of fish for mercury content need be done only once per year.

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ANNEXURE I

Fish and Fisheries of Kurram Tangi Dam Project Area by Dr. Sikender Hayat